Carbon Capture and Sequestration: A Primer

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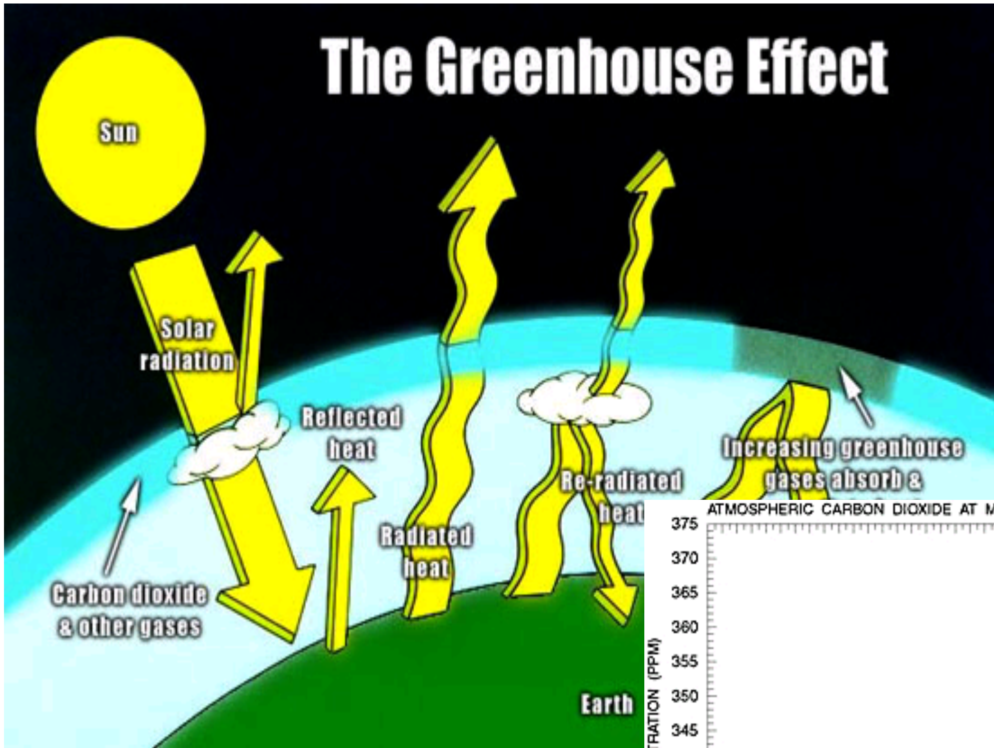
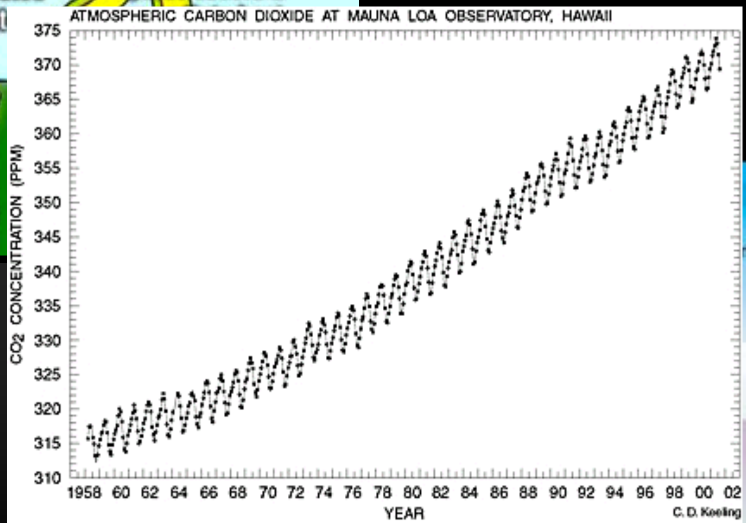
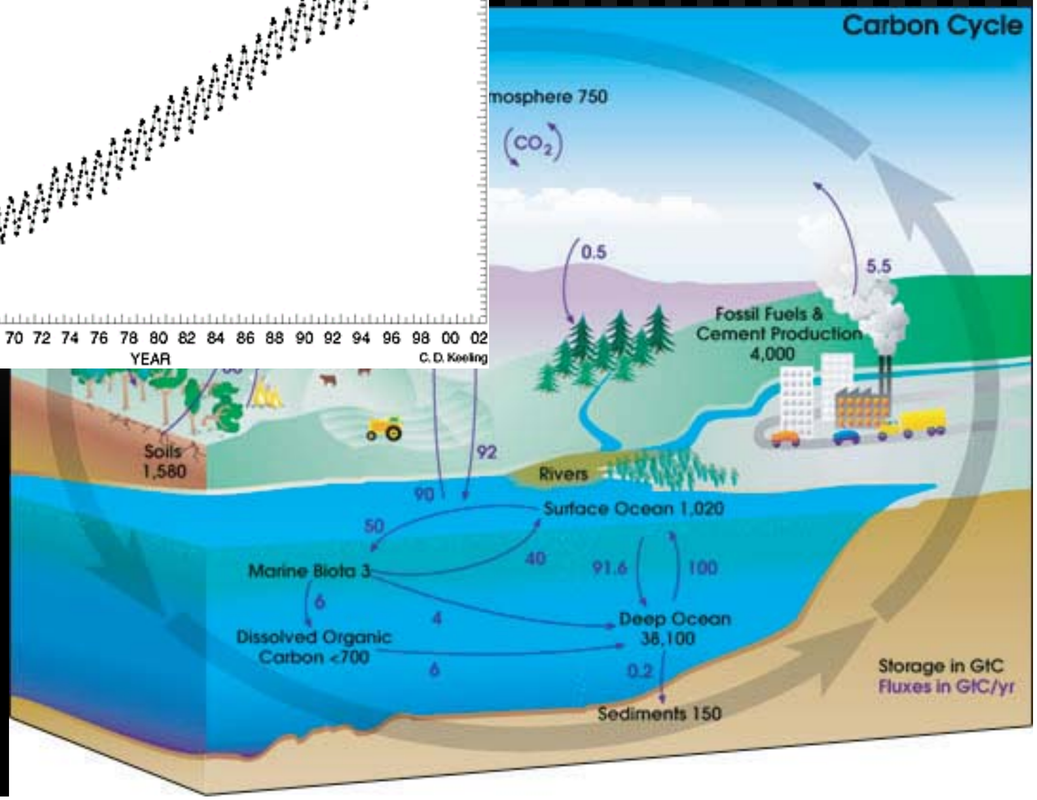
Presentation Summary

- Motivation: climate change mitigation
- CO_2 sequestration technology
- Status of proposed rule; Public health implications
- Current efforts relating to sequestration



Unmitigated CO_2 emissions…



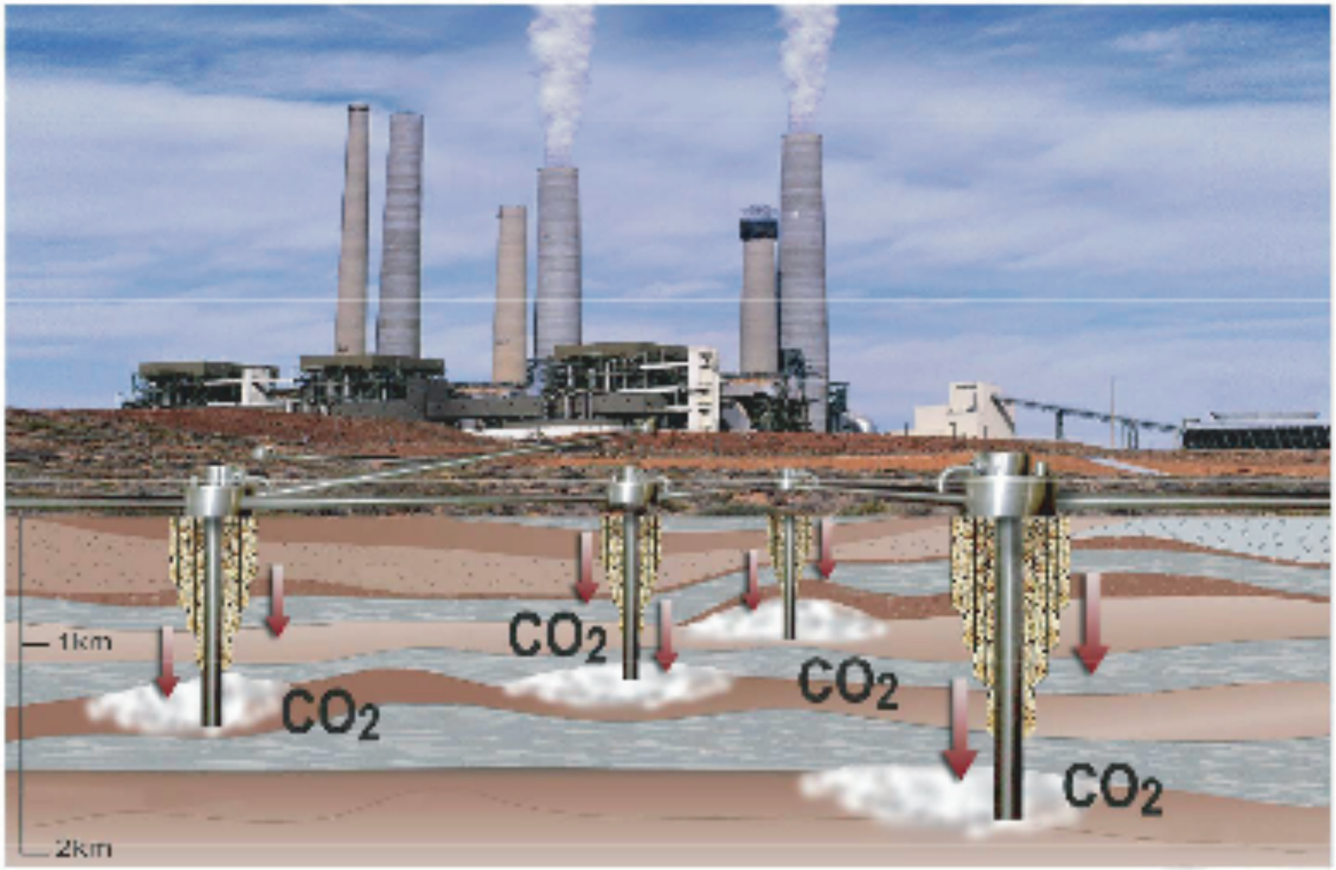


…are unsustainable.

What Can Be Done to Mitigate Greenhouse Gas Levels?

- Goal: stabilize CO_2 at 500 ppm in 50 years
- Requires holding emissions near the present level of 7 GtC/yr (BAU by 2055: 14 GtC/yr)
- **1 GtC/yr savings (1/7th necessary): Carbon capture and sequestration at 800 one GW coal power plants**
  - = Increase fuel economy for two billion cars from 30 to 60 mpg
  - = Increase wind power capacity by 50 times over current levels by adding 2,000,000 more 1MW windmills
  - = Double the current capacity of nuclear power, displacing coal generated power

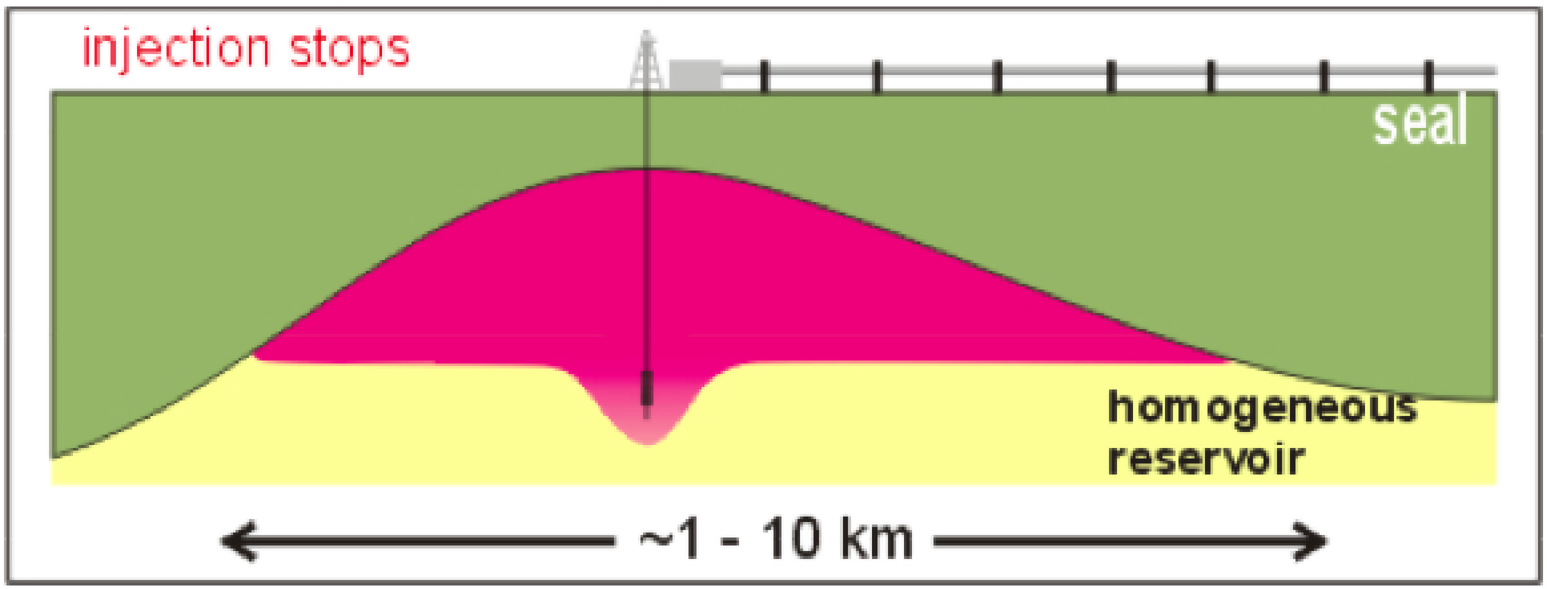
Carbon Dioxide Capture and Storage Involves 4 Steps



Capture → **Compression** → **Pipeline Transport** → **Underground Injection**

Basic Concepts

- Injected at depths of 1 km or deeper into rocks with tiny pore spaces
- Primary trapping
  - Beneath seals of low permeability rocks



Courtesy of John Bradshaw

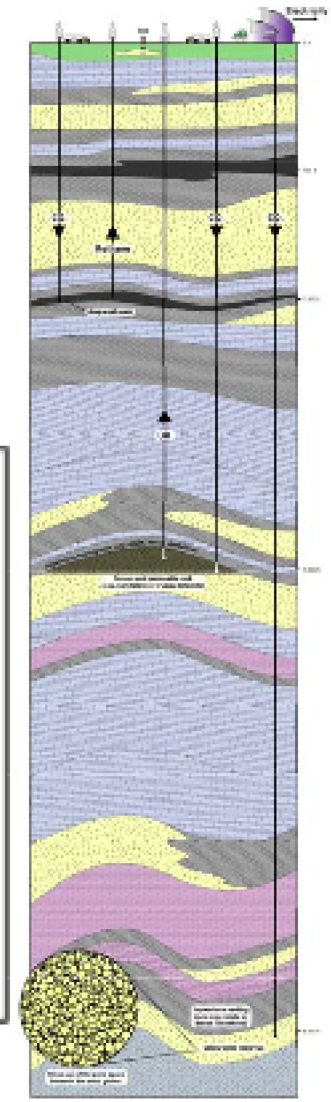
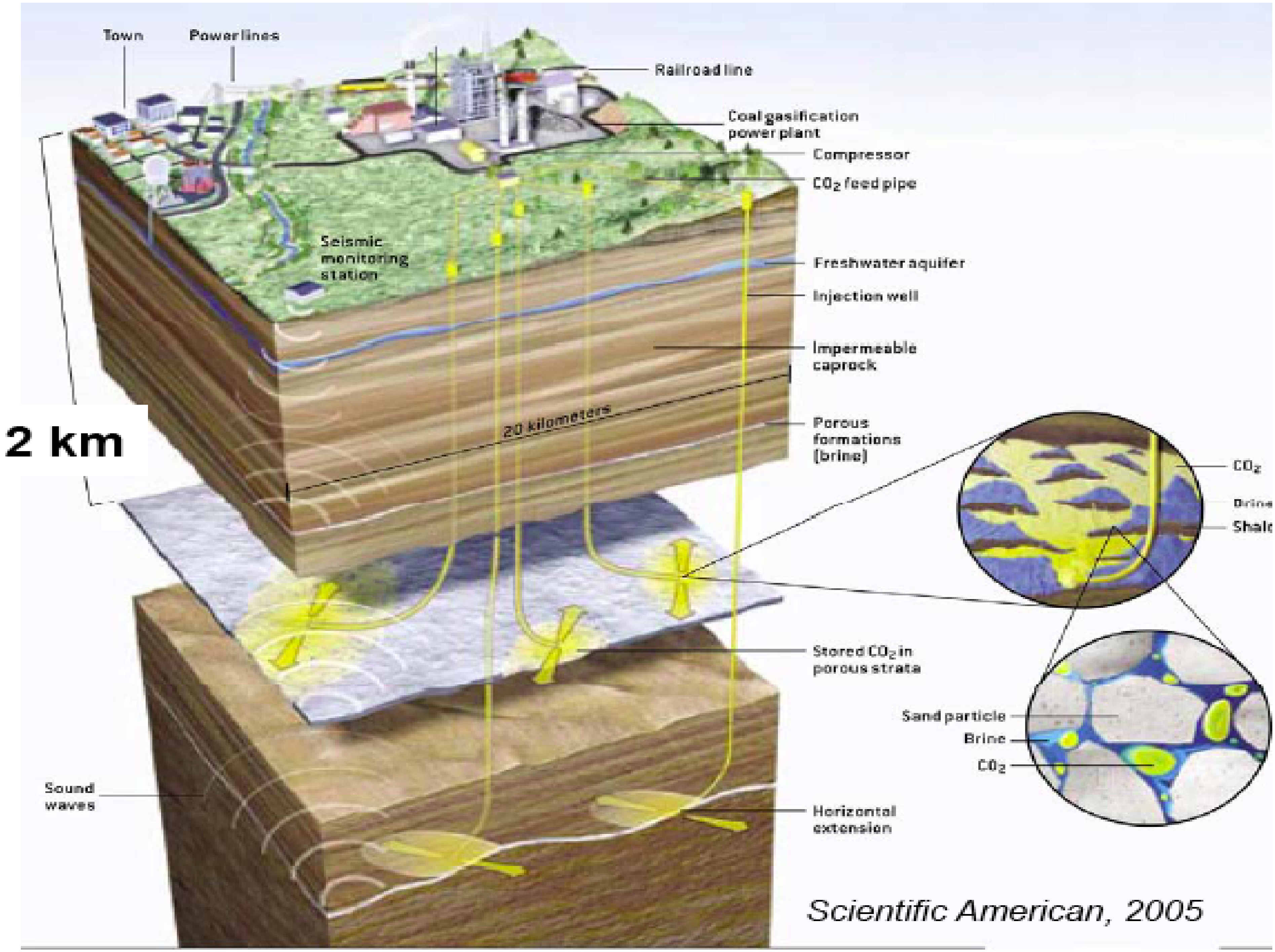
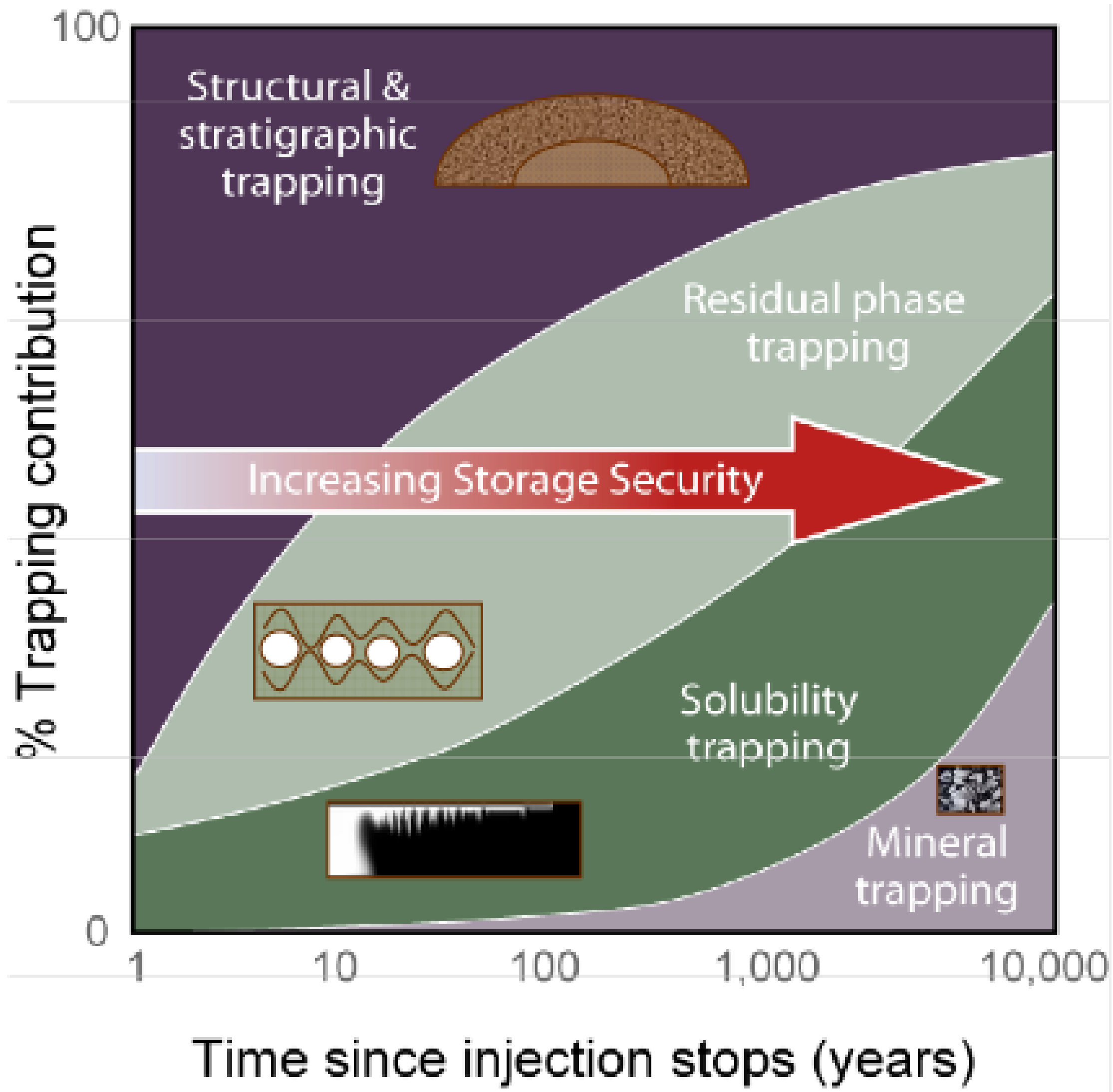


Image courtesy of ISGS and MGSC


Town
Power lines
Railroad line
Coal gasification power plant
Compressor
CO_2 feed pipe
Seismic monitoring station
Freshwater aquifer
Injection well
Impermeable caprock
20 kilometers
2 km
Porous formations (brine)
CO_2
Brine
Stored CO_2 in porous strata
Sand particle
Brine
CO_2
Sound waves
Horizontal extension
Scientific American, 2005

Secondary Trapping Over Time

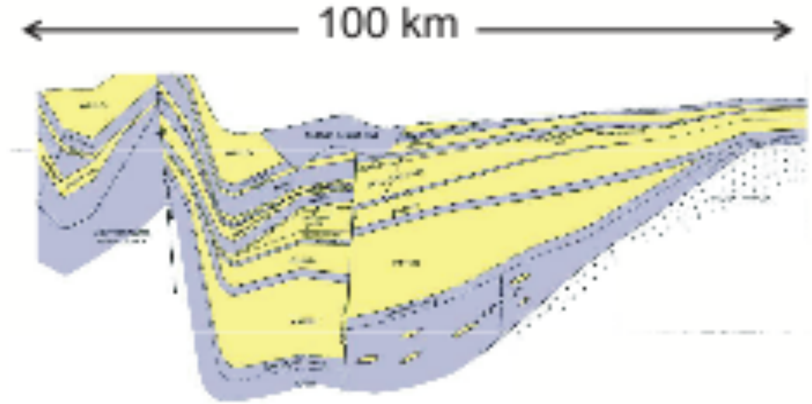
- Solubility trapping
  - CO_2 dissolves in water
- Residual gas trapping
  - CO_2 is trapped by capillary forces
- Mineral trapping
  - CO_2 converts to solid minerals
- Adsorption trapping
  - CO_2 adsorbs to coal



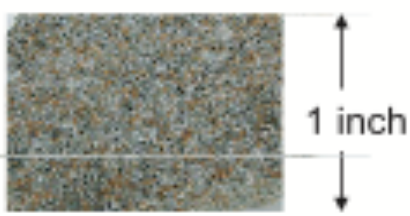
What Types of Rock Formations are Suitable for Geological Storage?

Rocks in deep sedimentary basins are suitable for CO_2 storage.

Map showing world-wide sedimentary basins



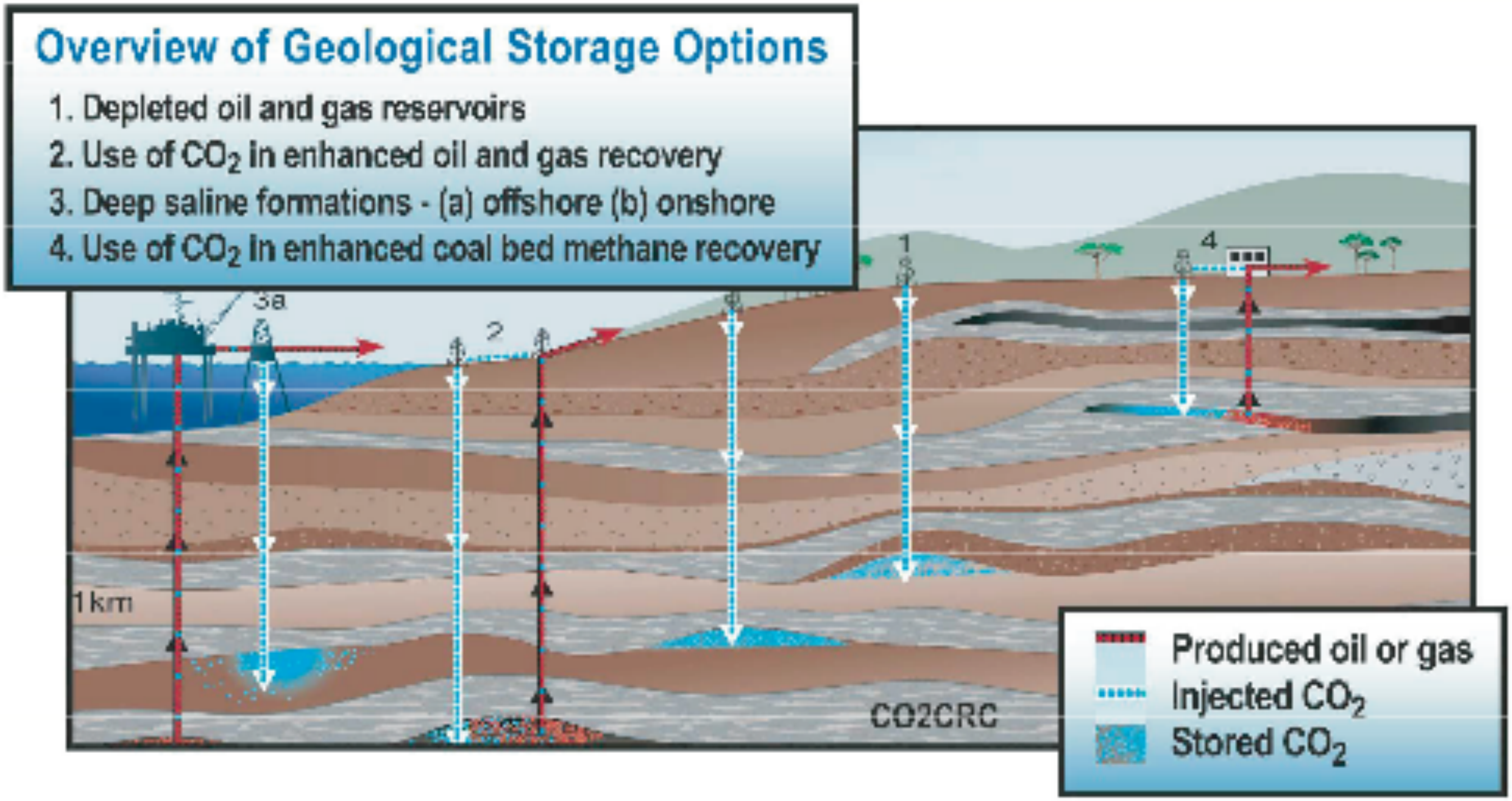
Northern California Sedimentary Basin



Sandstone

Example of a sedimentary basin with alternating layers of sandstone and shale.

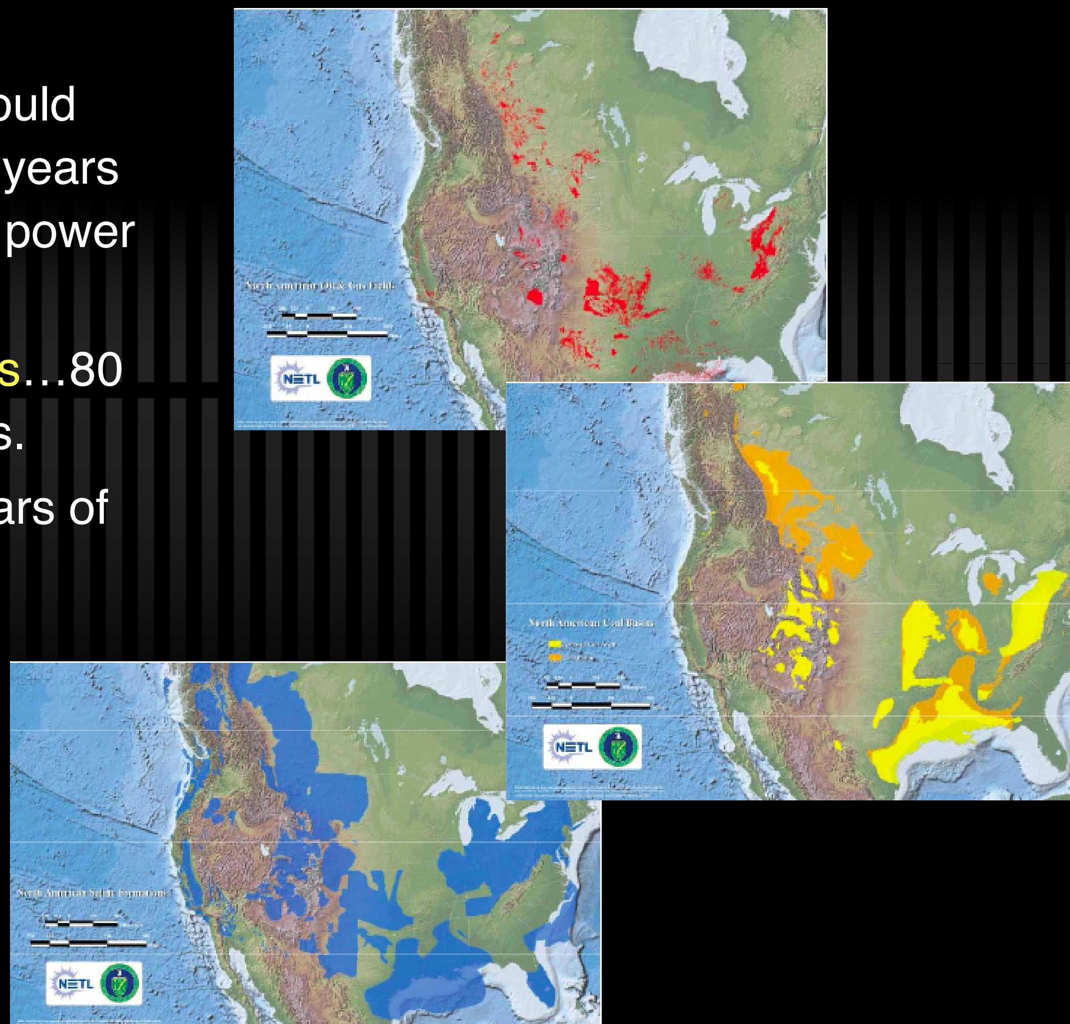
Options for Geological Storage



Storage Resources

- Oil and Gas Reservoirs could potentially store about 60 years of current emissions from power generation.
- Unminable coal formations…80 years of current emissions.
- Saline aquifers…1000 years of current emissions.

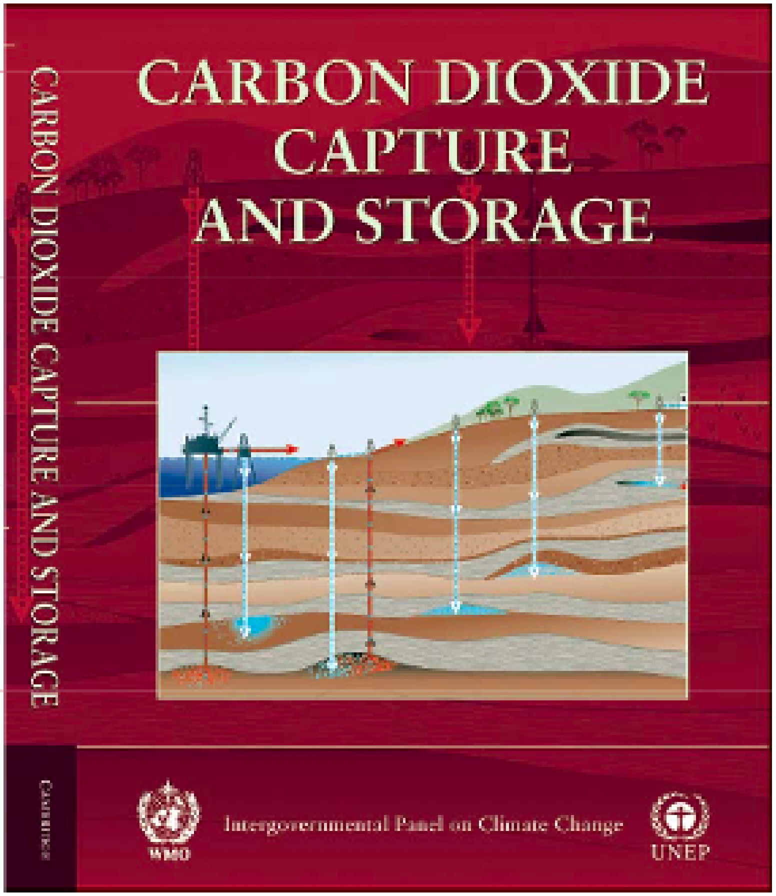
(national and CA)



Expert Opinion on Storage Safety

" Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely* to exceed 99% over 100 years and is likely** to exceed 99% over 1,000 years."

" With appropriate site selection informed by available subsurface information, a monitoring program to detect problems, a regulatory system, and the appropriate use of remediation methods to stop or control CO_2 releases if they arise, the local health, safety and environment risks of geological storage would be comparable to risks of current activities such as natural gas storage, EOR, and deep underground disposal of acid gas."

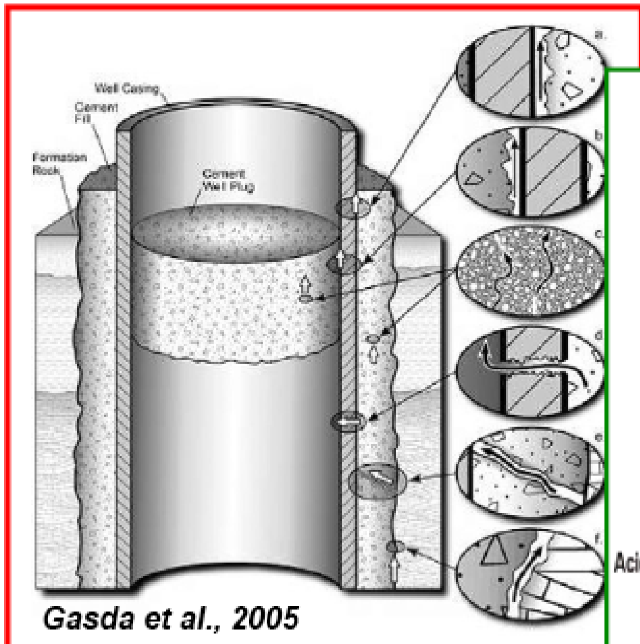


* "Very likely" is a probability between 90 and 99%.

** Likely is a probability between 66 and 90%.

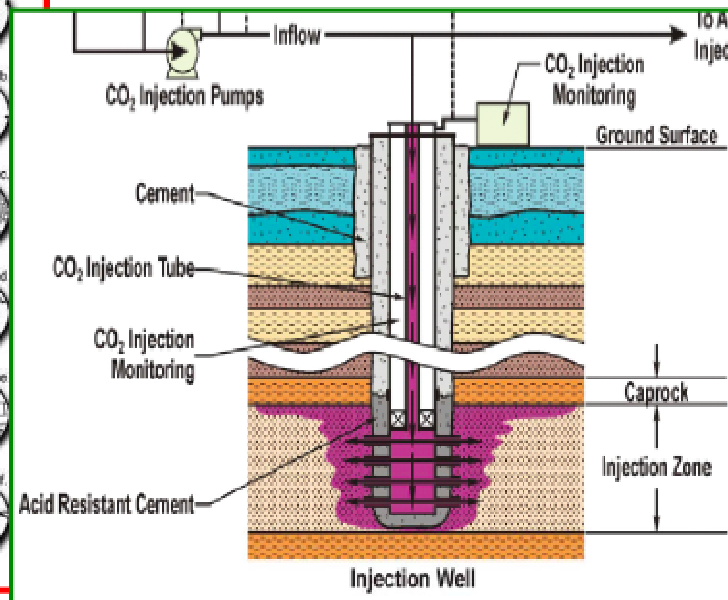
Wells represent the main hazard to GCS site integrity

We have some understanding of well failure modes

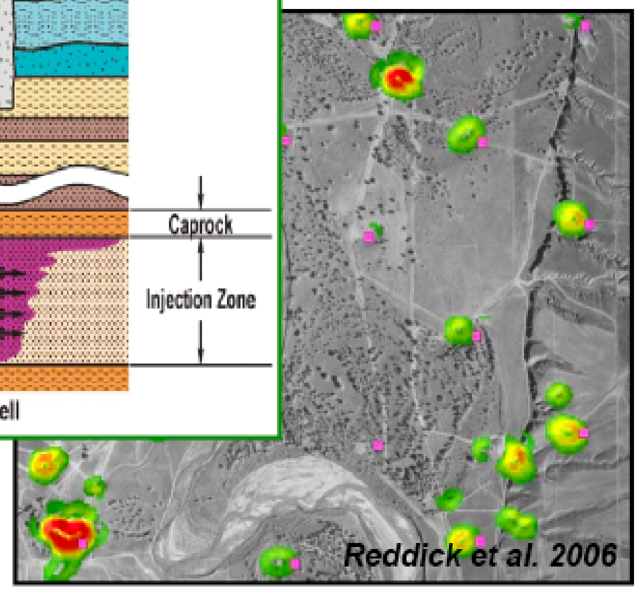


Gasda et al., 2005

We can properly design CO_2 wells and plug failed wells



Injection Well

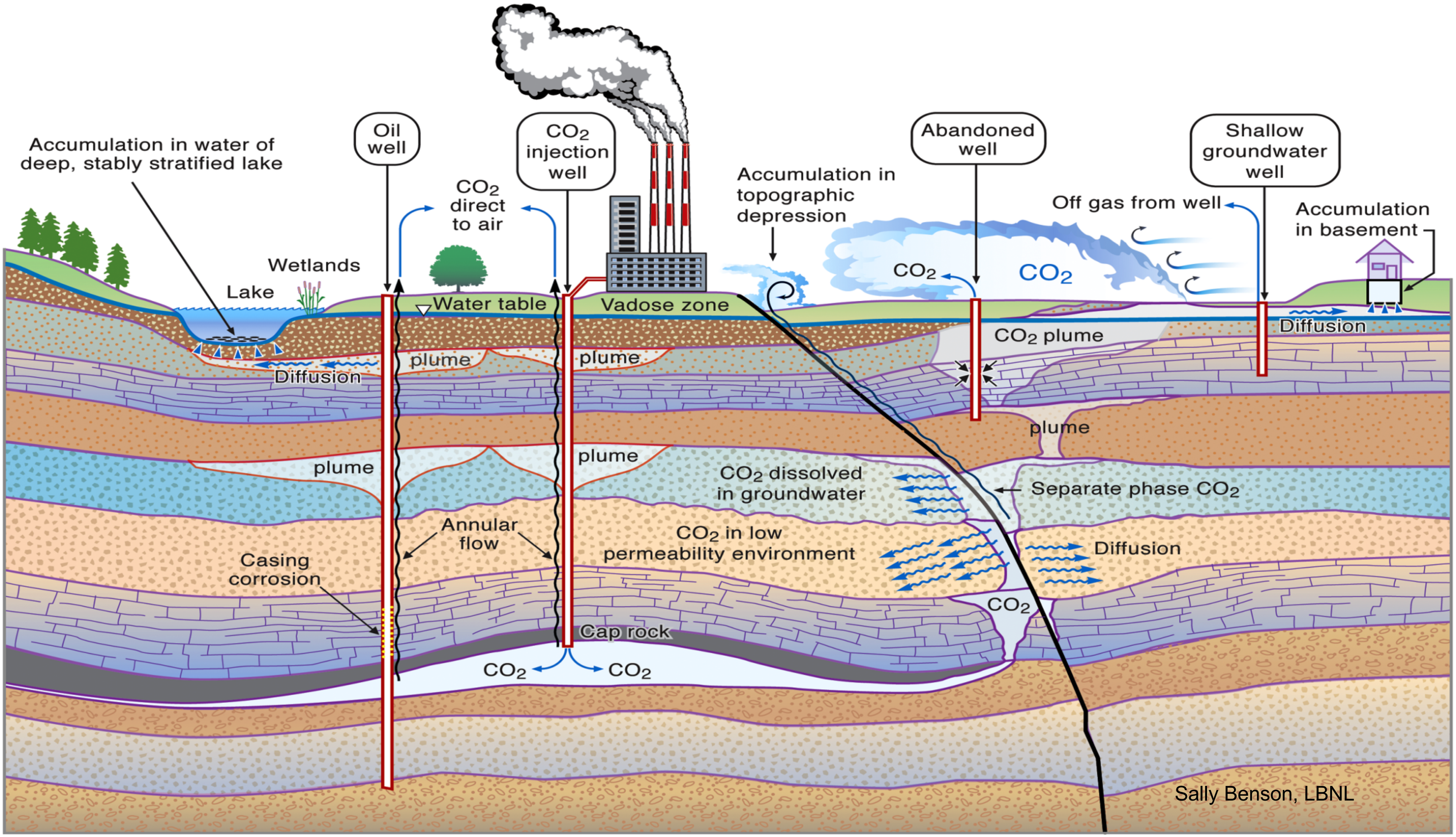


Reddick et al. 2006

We can identify and recomplete lost wells

Managing and maintaining well integrity is important to avoiding failure and risk minimization

Potential Leakage Pathways



The Lake Nyos event is not analogous to possible CCS leakage

The worst CO_2 release event in modern history

- *CO_2 accumulated in lake floor over 100's of years*
- *Released all at once: >1000 people died*

Two million tons CO_2 released overnight (probably in an hour)

- *The crust has great strength and great mass*
  - *catastrophic overturning not possible*
  - *flow rates from geological formations can't be this fast*
- *No deep lakes exist near any potential storage site in any OECD country*
- *This type of occurrence is easily detected and mitigated*

Current Actions

- Congress funding DOE pilot studies
  - WESTCARB, one of 7 national DOE partnerships characterize regional carbon sequestration opportunities and conduct technology validation field tests. The CEC manages WESTCARB, is a major co-funder.

Current Actions

October 2, 2009

Secretary Chu Announces First Awards from $1.4 Billion for Industrial Carbon Capture and Storage Projects

Washington, DC--U.S. Energy Secretary Steven Chu today announced the first round of funding from $1.4 billion from the American Recovery and Reinvestment Act for the selection of 12 projects that will capture carbon dioxide from industrial sources for storage or beneficial use.

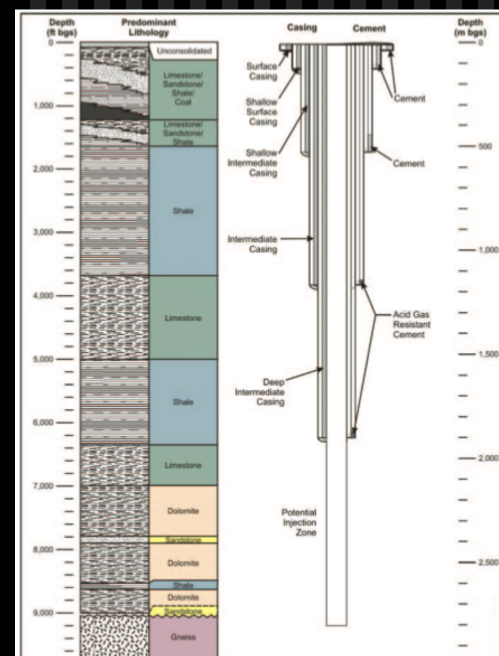
EPA Policy Decisions

- 2006 – EPA memo documented that:
  - CO_2 sequestration by injection falls under the UIC program of Safe Drinking Water Act
  - CO_2 injection related to pilot sequestration projects should be permitted as Class V experimental technology wells

EPA Policy Decisions

- July 5, 2008: Class VI Rule Proposed

  "Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO2) Geologic Sequestration (GS) Wells"
- Technical criteria for permitting GS wells to protect USDWs under SDWA using modified UIC Framework, including:
  - Geologic site characterization
  - Corrective action (nearby wells)
  - Well construction, operation, testing
  - Monitoring
  - Well plugging
  - Post-injection site care
  - Site closure
- Received 365 public comments (151 unique)



EPA Policy Decisions

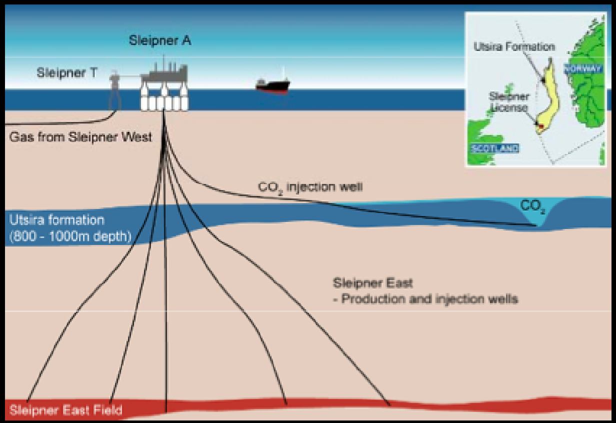
- August 31, 2009: Notice of Data Availability and Request for Comment (NODA)
  - Presents new data and information and requests public comment on related issues that have evolved in response to comments on the original proposal.
  - Contains:
    - Preliminary field data from the DOE-sponsored Regional Carbon Sequestration Partnership projects
    - Results of GS-related studies conducted by LBNL
    - Additional GS-related research
    - Discusses comments
    - Proposes variation on requirements below lowermost USDW
  - End of Comment Period: October 15, 2009
  - **Anticipated Final Rule: 2011**

NODA PWS Implications

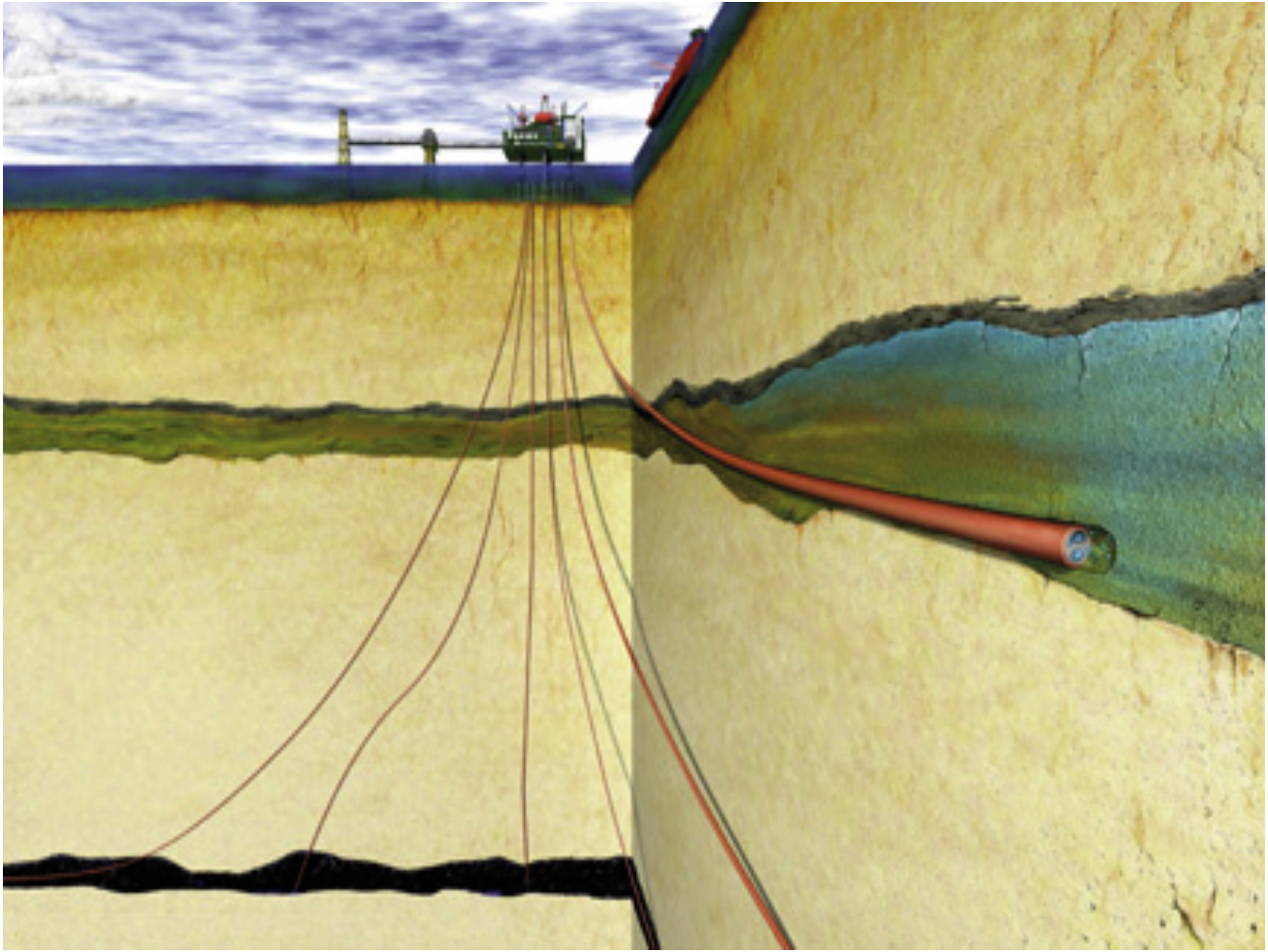
- Waiver for injection where very deep USDWs
- Unlikely to impact California/Region 9
- Information submitted to UIC and PWSS, requires approval by both offices
- Subject to local notice and public hearing

Current Sequestration Projects

Sleipner Field, Norway



- Location: Norwegian North Sea
- Project start date: 1996
- 2800 ton/day CO_2 storage in saline aquifer (1M t CO_2/year)
  - World's 1st commercial-scale storage of CO_2 for mitigation of climate change.
  - Injected into a large, deep saline reservoir 800M below the bed of the North Sea
- Monitoring results:
  - Confirming that CO_2 storage in deep saline reservoirs is a safe and reliable option
  - Supplying data to validate reservoir simulation models
  - Applicable in the planning of future CO_2 storage projects in other parts of the world



Region 9 (DOE/WC) CO_2 GS Projects

- AZ Cholla (Flagstaff)
  - 2,000 tons over < 1 month (equivalent to 1,000 MW coal-fired power plant emissions over 2.2 hours); monitored 3-5 months
  - Permitted 3/09; Update: injection zone inadequate permeability; will plug well, potentially move to new location
- Kimberlina (Bakersfield)
  - 250,000 tons/year for 4 years (zero-emissions plant)
  - Funding issues; LBNL efforts to be assigned to Shell
- Shell/C6 (Fairfield)
  - 2,000-6,000 tons over 1-2 months; monitoring well
  - Potential for commercial scale (DOE Grant -- $3M)
  - Technical review